APPENDIX E

Kinematic Formulas

The notation used to describe two-body kinematics is shown in Fig. E-1. The scattering treatment used for neutrons can be generalized to two-particle reactions by allowing the emitted particle mass to be different from the incident particle mass (*i.e.*, $m_3 \neq m_1$). Applying conservation of mass, energy, and momentum gives the following non-relativistic kinematic equations:

$$A = \frac{m_2}{m_1}\,, \tag{E.1}$$

$$A' = \frac{m_3}{m_1}\,, \tag{E.2}$$

$$\beta = \left(\frac{A(A+1-A')}{A'} \left[1 + \frac{1+A}{A} \frac{Q}{E_1} \right] \right)^{1/2} \tag{E.3}$$

$$\gamma = \frac{A'}{A+1-A'}\beta\,, \tag{E.4}$$

$$\frac{\varepsilon_3}{\varepsilon_1} = \frac{A'}{A^2}\beta^2\,, \tag{E.5}$$

$$\varepsilon_1 = \left(\frac{A}{A+1} \right)^2 E_1\,, \tag{E.6}$$

$$\mu_3 = \mu\,, \tag{E.7}$$

$$\frac{\varepsilon_4}{\varepsilon_1} = \frac{A'}{A+1-A'} \frac{\varepsilon_3}{\varepsilon_1}\,, \tag{E.8}$$

$$\mu_4 = -\mu\,, \tag{E.9}$$

$$\frac{E_3}{E_1} = \frac{A'}{(1+A)^2}\left(\beta^2 + 1 + 2\beta\mu\right), \tag{E.10}$$

$$\omega_3 = \frac{1+\beta\mu}{\sqrt{\beta^2+1+2\beta\mu}}\,, \tag{E.11}$$

$$\frac{E_4}{E_1} = \frac{A + 1 - A'}{(1 + A)^2} \left(\gamma^2 + 1 - 2\gamma\mu\right), \tag{E.12}$$

$$\omega_4 = \frac{1 - \gamma\mu}{\sqrt{\gamma^2 + 1 - 2\gamma\mu}} . \tag{E.13}$$

If the incident and scattered particles are the same, A′=1, and these formulas reduce to the familiar set used for neutron scattering. The elastic reaction corresponds to A′=1 and Q=O.

According to these formulas, the secondary energy distribution of the emitted particle and the complete energy-angle distribution of the recoil nucleus are completely determined by A, A′, Q, and the angular distribution for the emitted particle.

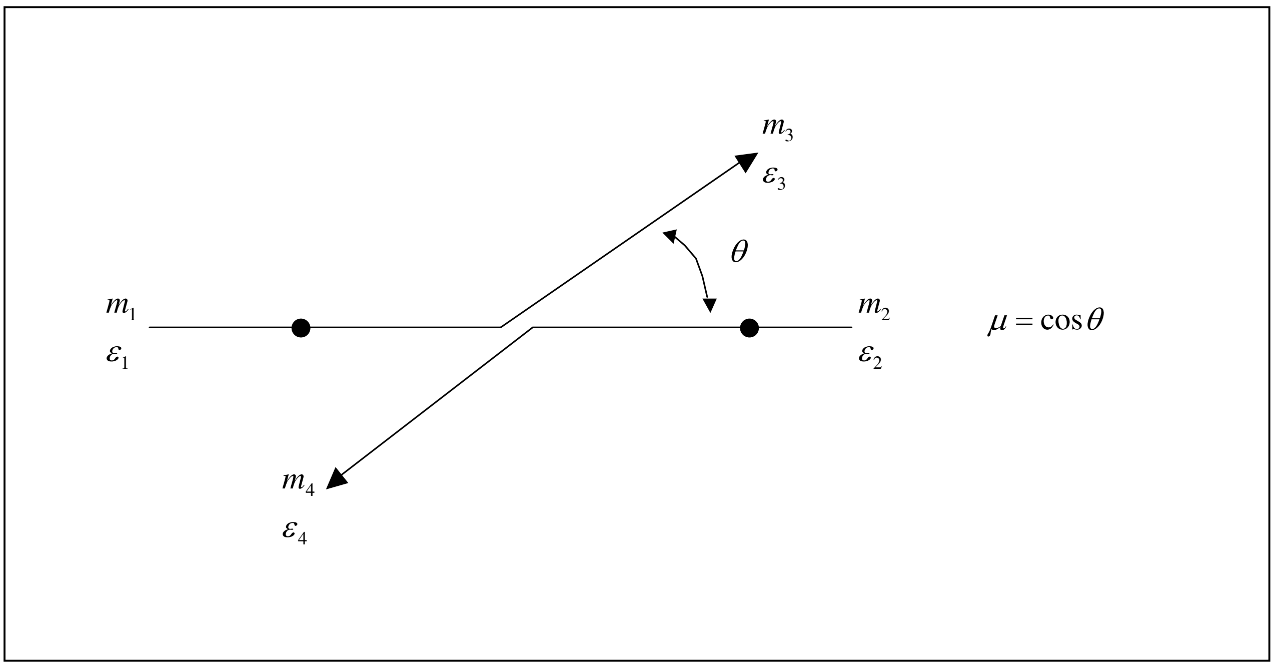

Figure E.1
Kinematics Variables for Two-Particle Reactions
Center-of-Mass System

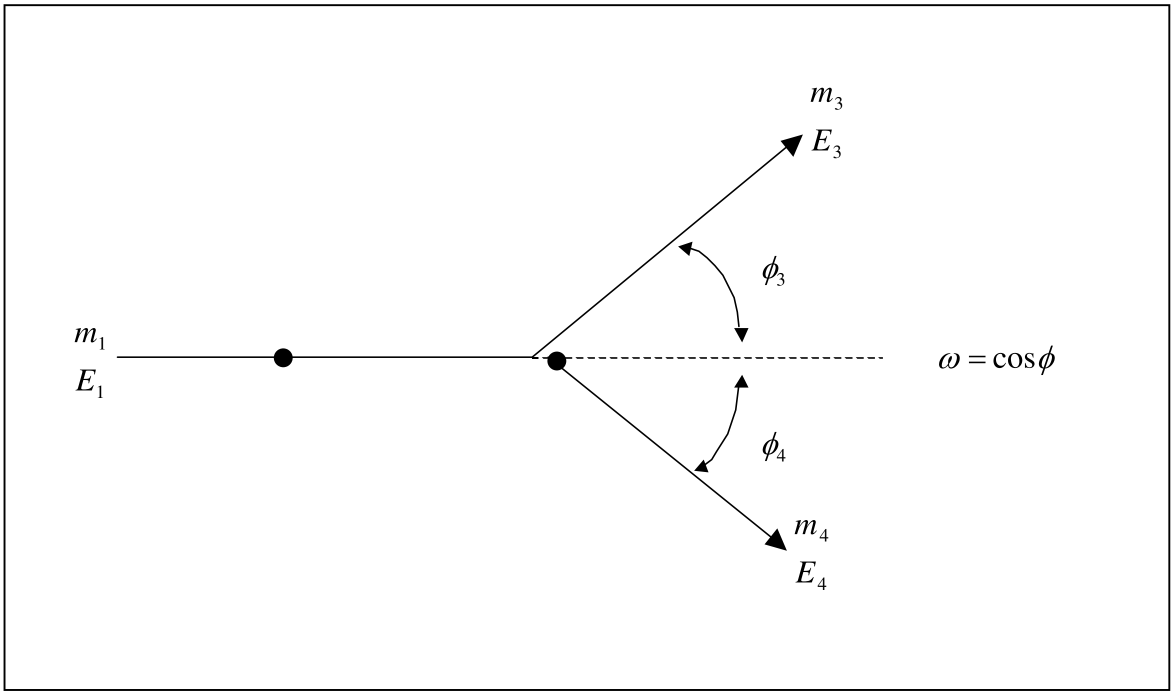

Figure E.2
Kinematics Variables for Two-Particle Reactions
Laboratory System